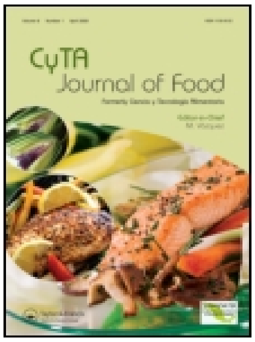

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USE OF POTASSIUM PERMANGANATE IN THE SUGAR APPLE POST-HARVEST PRESERVATION

USO DE PERMANGANATO DE POTASIO EN LA PRESERVACIÓN POST-COSECHA DE FRUTAS DE CHIRIMOYA

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Abstract

The objective of this work was to evaluate the effect of the concentration of $KMnO_4$ on post-harvest parameters of the sugar apple fruit (*Annona squamosa*, L.) packed in 0.1mm thick PVC films. Groups of 4 fruits and a TNT bag with $KMnO_4$, were wrapped in a PVC film and kept in a cold chamber at 16 °C with relative humidity between 90 and 100 %. A random experimental design was used in a 5 x 4 factorial scheme. The relationship of total soluble solids/titratable acidity presented different behavior comparing to the other variables, though it was possible to establish reasonable correlation taking the permanganate level and the storage time as independent variables and one of the following as a dependent variable: soluble solids level, pH, titratable acidity and weight loss. It was concluded that $KMnO_4$ delayed the maturity of the fruits, increased the period for fruits to hit maximum solid solutes content and increased the pH when it reached consumption period. It also decreased the titratable acidity.

Resumen

El objetivo de este trabajo, fue evaluar el efecto de la concentración de $KMnO_4$ sobre algunos parámetros de poscosecha de la fruta de chirimoya (*Annona squamosa*, L.), empacadas con películas de PVC de 0,1mm de espesor. Grupos de 4 frutas y una bolsa de TNT con $KMnO_4$, fueron envueltas en una película de PVC y colocados en una cámara a 16 °C con humedad relativa entre 90 y 100 %. El diseño experimental fue totalmente al azar en un esquema factorial 5 x 4. La relación sólidos solubles/acidez titulable presentó un comportamiento diferente a las otras variables pero fue posible establecer buenas correlaciones entre el nivel del permanganato o el tiempo de almacenamiento con cada una de las siguientes variables dependientes: contenido de sólidos solubles, pH, acidez titulable y pérdida de peso. Se concluye que el efecto del $KMnO_4$ fue retardar la maduración de las frutas aumentando el tiempo necesario para alcanzar el contenido máximo de sólidos solubles y el pH que tendrían al momento del consumo. El $KMnO_4$ también diminuyó la acidez titulable.

Keywords: Sugar apple, potassium permanganate, titratable acidity
Palabras clave: Chirimoya, permanganato de patasio, acidez tituable

INTRODUCTION

Despite being a highly appreciated fruit by consumers due to its excellent taste, sugar apple (*Annona squamosa*, L.) faces commercialization problems because of its perishableness. At room temperature, the post-harvest shelf life of this fruit is only three to four days. For this reason it is only commercialized in the domestic market. Short shelf life, when associated with inadequate handling, results in production loss and hinders sugar apple commercialization. An immediate consequence is a raise of the product's price. Therefore, it is necessary to develop a technology which enables to extend the sugar apple post-harvest shelf life, reaching the consumer with its sensory qualities minimally altered and at compensatory prices.

Although official statistics are non-existent, the growing demand for annonaceae fruits is widely known, both in Brazilian domestic and in foreign markets. This is observed regarding the demand of publications about production, harvesting and post-harvesting of sugar apple and soursop (Mosca *et. al.,* 2003).

There are two classes of fresh products in terms of ethylene production. There are climacteric products, mainly fruits that produce a burst of ethylene as ripen, as well an increase in respiration and there are the non-climacteric products that do not increase ethylene production when ripen. The more obvious way to establish in which class a product fits in is whether or not the product ripens after harvest. Products that ripen after harvest are classified as climacteric and they typically ripen by significantly softening, by changing color and by becoming sweeter (examples are bananas and nectarines). Non-climacteric fruits do not change significantly after harvest. They will soften a little, lose green color and develop rots as they become old but they do not improve their eating characteristics. Nonclimacteric crops include leafy vegetables, strawberries and grapes (Jobling, 2007).

Annonaceae fruits, such as the sugar apple, are climacteric as they increase respiratory activity and production of ethylene during ripening (Araujo *et al.*, 1999). The increase of respiratory activity is accompanied by rapid modifications in its chemical composition, which alter the taste, aroma, firmness of the pulp and skin color. The development of suitable technology would enable the fruits quality conservation and would enable their shelf life prolongation (Kavati, 1997).

The use of PVC (polyvinyl chloride) film to create a modified atmosphere has shown satisfactory results for many fruits like guava and passion fruit, and has reduced loss of fresh weight (Lima and Durigan, 2000; Floriano *et al.*, 2003). Santiago *et al.* (2003) noted a reduction in weight loss of fruits stored in PVC packing for sugar apples.

Among the large number of reagents and techniques that have been tested over the past years to remove ethylene from storage rooms whithout ventilation, potassium permanganate is the commercially used. A number of commercial potassium permanganate scrubbers are available in sachets, filters, blankets, and other specialized trapping devices (Sherman, 1985).

The inclusion of potassium permanganate, which is an ethylene absorbent, aims an extension of the storage period (Salunkhe and Desai, 1984).

When potassium permanganate in combination with polyethylene film is utilized, there is a longer fruit ripening delay (Chamara *et al.*, 2000). Jiang *et al.* (1997) found that PVC packing (0.07 mm thickness) containing ethylene absorbers, K_2MnO_4-amargosite and $KMnO_4$, respectively, was more efficient in prolonging conservation of post-harvest bananas, by offering a longer pre-climacteric period. Strawberries, packed in PVC film containing ethylene absorbent ($KMnO_4$) stored at low temperatures, showed a decrease in respiratory rate and an increase in storage life from 20 to 30 days, maintaining the relationship sugars/acids acceptable for consumption (Hao and Hao, 1993). A higher value of total soluble solids/total titratable acidity (TSS/TTA) relationship indicates an agreeable taste due to the excellent combination of sugar and acid, while lower values correlate to acidity and bitter taste.

Experimental conditions utilized by various authors (Corrêa *et al.*, 1995; Hong *et al.*, 1996; Bhadra and Sen, 1997; Toivonen and Gorny, 1997; Yon *et al.*, 1997; Kim and Wills, 1998) vary regarding polyethylene film thickness, with or without perforations, either using or not ethylene absorbers, or temperature, etc. Nevertheless, all of them concluded that polyethylene film packing, together with ethylene absorbers and low temperatures, led to a considerable increase in fruits shelf life, by increasing CO_2 concentration, reducing water loss and respiration, inhibiting ethylene activity and consequently reducing the metabolism of the fruit.

The objective of this work was to evaluate the effect of the concentration of $KMnO_4$ on post-harvest parameters of the sugar apple fruit (*Annona squamosa*, L.) packed in 0.1mm thick PVC films.

MATERIAL AND METHODS

Sugar apple fruit (*Annona squamosa*, L.) was picked up at its physiological ripeness stage, in the neighborhood of Rancho Alegre property (Latitude 14º 26' 56'' S, Longitude 41º 04' 41'' W and altitude 330m), in the city Anagé, Bahia, Brazil. The experimental period was from June to October 2003. The local climate can be classified, according to Koppen, as semi-arid and very hot, of the Bswh' type (Silva, 2004). The local soil is characterized as Tropic Eutrophic Haplic Cambisol Tb Class, which offers good drainage conditions (Silva, 2004).

According to Gaspar *et al.* (2000) the chemical and physical properties of sugar apple are affected by local factors such as soil and climate. This can also affect maturation period and the fruit's characteristics at consumption. The fruits from this property are being routinely accompanied by researchers from UESB. They have shown the following average characteristics of physiological ripeness: average weight of 350 g; pH 5.65; total soluble solids (TSS) 21.5 ^{o}Brix and total titratable acidity (TTA) 0.40 % of citric acid. When fully ripened: average weight of 392 g; pH 5.3; total soluble solids (TSS) 25 ^{o}Brix and total titratable acidity (TTA) 0.39 % of citric acid (Ferrari *et al.*, 1998; Gaspar *et al.* 2000; Silva *et al.*, 2002; Dias *et al.*, 2003). These characteristics were taken as reference in this work. The fruits were picked up and selected at the property and transported to the UESB Process Engineering Laboratory - Itapetinga Campus where they were treated and packed on the same day.

Groups of 4 fruits were randomly separated and weighed. Based on the weight of these fruits the $KMnO_4$ weight was calculated to be packed together. The $KMnO_4$ was put into a TNT (short for Tissue Not Tissue, which is a non specified synthetic polymer) bag and placed among the four fruits on an expanded polyestirene tray. The tray and fruits were wrapped in a PVC film and sealed in a manual sealer.

After packing, the fruits were kept in a cold chamber at 16 °C and relative humidity between 90 and 100%. pH (measured with a digital pH meter, QUMIS®), total soluble solids (measured with a portable ATAGO refractory meter), titratable acidity and weight loss (measured with an analytical GEAKA pair of scales) were analyzed according to the Adolfo Lutz Institute Rules (1995). A visual analysis of the inside and outside parts of the fruits was also performed. The experimental characterization used was entirely done in a 5 x 4 factorial scheme (5 levels of chemical factor: $KMnO_4$ control at 3, 6, 9, and 12 %, respectively and 4 levels of time factor: 2, 4, 7, and 12 days of storage), with 12 repetitions. The experimental unit was one tray with 4 fruits.

The results were analyzed by multiple regression analysis using the Sagata Regression Pro «statistical package». A quadratic model was utilized. The independent variables were the permanganate content and the number of post-harvest days. The dependent variables were individually: weight loss, total soluble solids content, pH, titratable acidity and total soluble solids/titratable acidity relationship. Insignificant coefficients at 5% probability, from the Tukey test, were removed from the completed model. The deviations observed between and estimated values were also analyzed by residue graphs.

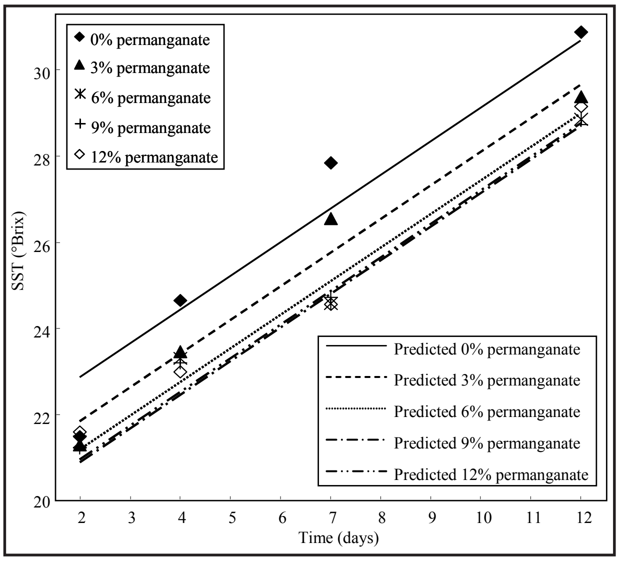

Figure 1. Soluble solids content as a function of storage time (at 16 °C and relative humidity above 90%) and permanganate level inside the PVC film packing, for sugar apple fruits (*Annona squamosa*, L.).

Figura 1. Volumen de sólidos solubles en función del tiempo del almacenamiento (a 16 °C y humedad relativa >90%) y los niveles del permanganato dentro de la película de PVC, para chirimoya (*Annona squamosa*, L.).

RESULTS AND DISCUSSION

The initial average values of fruit weight, pH, total soluble solids (TSS), total titratable acidity (TTA) and TSS/TTA relationship were: 0.408±0.2 kg, 5.61±0.01, 21.4±0.1 °Brix, 0.348±0.005 % of citric acid and 63.2±0.8 °Brix/% citric acid, respectively. These values are very close to the historic average values from the property which were taken as reference.

Total soluble solids (TSS) content increased during storage period (Figure 1). The regression model found, Equation 1, takes into consideration only the linear effect of time period and the linear and quadratic effects of the permanganate content. As permanganate concentration gets higher, more time will take for soluble solids content to approximate the ripening level. Santiago *et al.* (2003) and Guimarães *et al.* (2003) observed the plastic packing effect on the delay in increasing soluble solids in sugar apple (*Annona squamosa*, L.). In this study, it was found that the increase in permanganate contributed to an increase of delay.

$$TSS = 21.31 + 0.78T - 0.40M + 0.02M^2 \quad (1)$$

Where: T is the time period in days and M is the permanganate level (% w/w). $R^2 = 0.970$.

The pH of the fruits showed a decrease during storage period (Figure 2). In this case, the regression model found (Equation 2) corresponds to the complete quadratic

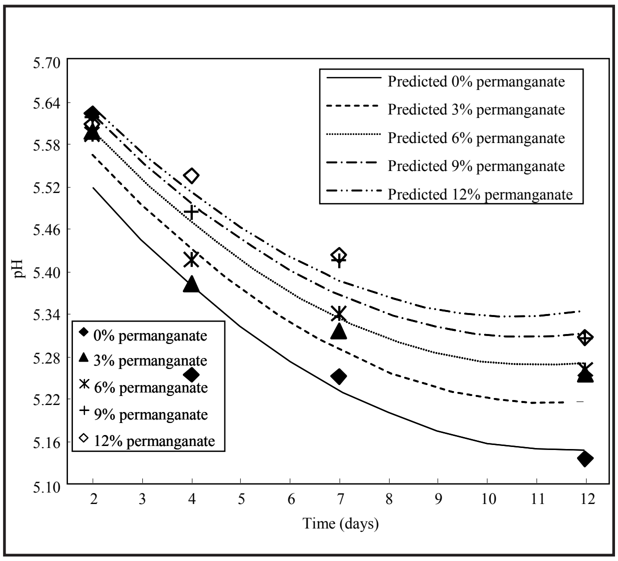

Figure 2. pH as a function of storage time period (at 16 °C and relative humidity above 90%) and permanganate level inside the PVC film packing, for sugar apple fruits (*Annona squamosa*, L.).

Figura 2. pH en función del tiempo del almacenamiento (a 16 °C y humedad relativa > 90%) y los niveles del permanganato dentro de la películas de PVC, para chirimoya (*Annona squamosa*, L.).

grade model. Santiago *et al.* (2003) did not observe the effect of plastic film packing on pH of sugar apple fruits, which indicates that the observed decrease here may be attributed to the permanganate.

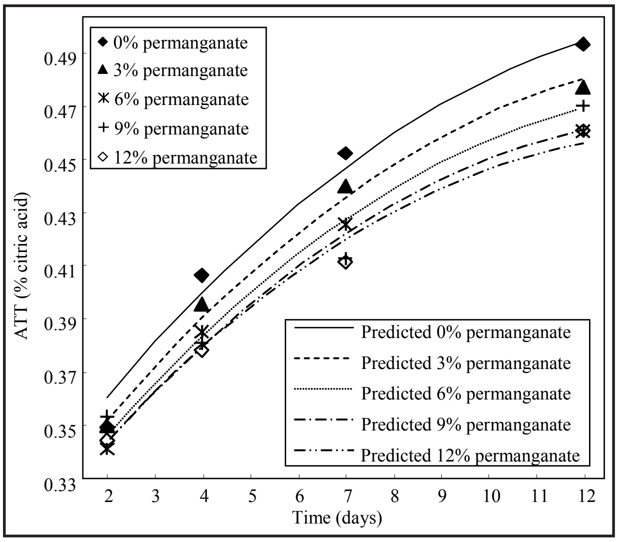

Figure 3. Titratable acidity as a function of storage time period (at 16 °C and relative humidity above 90%) and permanganate level inside the PVC film packing, for sugar apple fruits (*Annona squamosa*, L.).

Figura 3. Acidez titulable en función del tiempo del almacenamiento (a 16 °C y humedad relativa > 90%) y los niveles del permanganato dentro de la película de PVC, para chirimoya (*Annona squamosa*, L.).

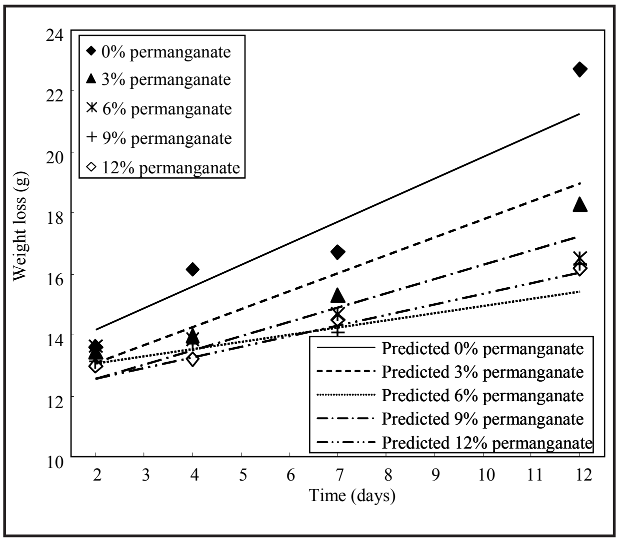

Figure 4. Weight loss as a function of storage time period (at 16 °C and relative humidity above 90%) and permanganate level inside the PVC film packing, for sugar apple fruits (*Annona squamosa*, L.).

Figura 4. Pérdida de peso en función del tiempo del almacenamiento (a 16 °C y humedad relativa >90%) y los niveles del permanganato dentro de la película de PVC, para chirimoya (*Annona squamosa*, L.).

$$pH=5.6912-0.0938T+0.0160M+0.0041T^2-0.0007M^2+0.0007TM \quad (2)$$

Where: T is the time period in days and M is the permanganate level. R^2=0.901.

Titratable acidity increased as stored (Figure 3). In this case, it was observed that an increase in the permanganate level inside the packing reduced the titratable acidity, consequently increasing the period for this variable to reach values equivalent to the property's historic values for ripe fruits. In this case the obtained regression model (Equation 3) was also the complete quadratic model, showing the linear and quadratic effects of time period and permanganate levels, as well as the importance of the variables interaction.

$$TTA=0.3148+0.0245T-0.0031M-0.0008T^2+0.0002M^2-0.002TM \quad (3)$$

Where: T is the time period in days and M is the permanganate level (% w/w). R^2 = 0.984.

A weight loss increase was noted during storage period (Figure 4). The linear period effect of storage and the linear and quadratic effects of the permanganate level in the packing were observed for this variable. The effect of the product time period X permanganate levels was also observed. Equation 4 is the regression model obtained for this variable. Weight loss progressive increase was also observed by Guimarães *at al.* (2003) who studied the storage of sugar apple fruits in PVC packing, without the addition of permanganate. It was observed from this work that the use of permanganate reduced weight loss intensity in relation to the control group which did not pass through treatment.

$$WL = 12.75 + 0.71T - 0.37M + 0.03M^2 -4TM;\ R^2 = 0.921 \quad (4)$$

Where: WL is the weight loss, T is the time period in days and M is the permanganate level (% w/w).

The results showed $KMnO_4$ effect delayed fruits maturity, increased the period for fruits to reach maximum solid solutes content and increased pH of the fruit when it reaches consumption moment. It also decreased the titratable acidity. Contrary to other variables studied, the multiple regression quadratic model did not adjust to total soluble solids level and total titratable acidity (TSS/TTA) relationship. A simple linear regression equation for each level of permanganate was obtained for this variable (Figure 5 and Equations from 5 to 9).

$$TSS/TTA = 62.26 + 0.21M + 0.02M^2;\ R^2 = 0.834 \quad (5)$$
$$TSS/TTA = 64.77 + 0.92M + 0.07M^2;\ R^2 = 0.833 \quad (6)$$
$$TSS/TTA = 64.71 + 1.19M + 0.10M^2;\ R^2 = 0.892 \quad (7)$$
$$TSS/TTA = 66.27 + 1.48M + 0.10M^2;\ R^2 = 0.827 \quad (8)$$
$$TSS/TTA = 64.07 + 0.87M + 0.07M^2;\ R^2 = 0.951 \quad (9)$$

A rapid reduction in TSS/TTA relationship levels was observed in all treatments from the second to fourth day of storage. From then all the values increased. This probably occurs because titratable acidity increased

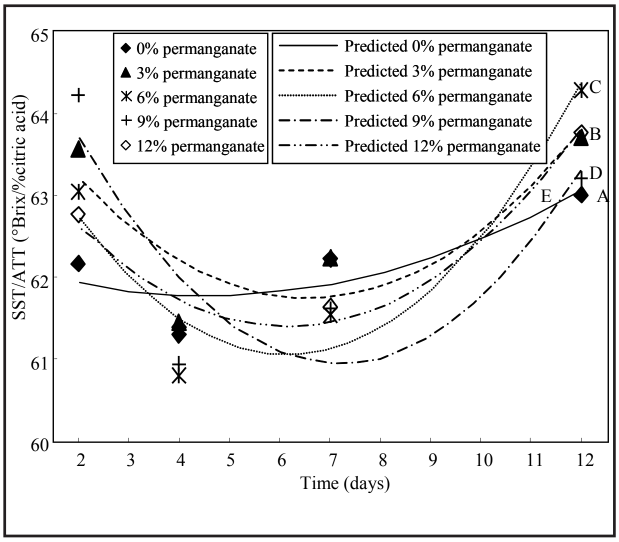

Figure 5. TSS/TTA as a function of storage time period (at 16 °C and relative humidity above 90%) and permanganate level inside the PVC film packing, for sugar apple fruits (*Annona squamosa*, L.).

Figura 5. TSS/TTA en función del tiempo del almacenamiento (a 16 °C y humedad relativa sobre 90%) y los niveles del permanganato dentro de la película de PVC, para chirimoya (*Annona squamosa*, L.).

rapidly during day zero to four and it is not accompanied by the level of soluble solids. Resende *et al*. (2001) utilizing benomyl and potassium permanganate in passion fruit reported a delay in (TSS/TTA) relationship and attributed the same to ethylene absorber, which role is to absorb and oxidize the ethylene liberated by the fruit itself during ripening. It is known that ethylene accelerates the ripening process, and its oxidation by ethylene absorber leads to a ripening delay. Nevertheless, we could observe in this work that this effect only took place in TSS/TTA relationship levels after the fourth day of storage.

Control group fruits were fully ripened on the fourth day. Their TSS/TTA and pH levels were equivalent to the properties‘ historic values.

For the treatment with $KMnO_4$ 3 and 6 %, the complete ripening occurred between the fourth and seventh day and consumption might be on the seventh day. On the twelfth storage day, some of the fruits had a pinkish color inside, which probably would lead to their disposement by the consumer. Various authors, among whom we quoted Mosca *et al.* (2003) and Guimarães *et al.* (2003), reported the skin darkening as an undesirable factor, though common in sugar apples. However, nothing was found in literature regarding the pinkish coloring.

For the treatment with $KMnO_4$ 9 % and 12 % treatments, full ripening occurred between the seventh and twelfth day, and the fruits were in good condition to be consumed. Guimarães *et al.* (2003) also reported that on the 12th day fruits that were packed in plastic film had a better internal appearance than the unpacked ones.

CONCLUSION

From the obtained results it can be concluded that it was possible to establish satisfactory correlations taking permanganate level and the storage time period as independent variables and as dependent variables, one of the following: soluble solids level, pH, titratable acidity and weight loss. Although not all the models obtained were linear models.

The maturity of the fruits was delayed by the treatments with $KMnO_4$, increasing the period for fruits to reach maximum solid solute content and increasing their pH when consumption moment is reached. It also decrease the titratable acidity.

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